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Rocket Measurements of the Electron Density in the Ionosphere

by
T. A. Croft

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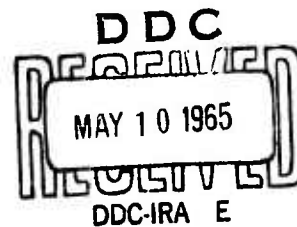
March 1965

Technical Report No. 98

Prepared under

Office of Naval Research Contract
Nonr-225(64), NR 088 019, and

Advanced Research Projects Agency ARPA Order 196-65



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STANFORD ELECTRONICS LABORATORIES

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ROCKET MEASUREMENTS OF THE ELECTRON DENSITY
IN THE IONOSPHERE

by

T. A. Croft

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Radioscience Laboratory
Stanford Electronics Laboratories
Stanford University Stanford, California

ABSTRACT

In the two decades since the end of World War II, a large number of rocket launches have been conducted to measure electron density in the ionosphere. Although each single measurement has its own interesting features, more can be learned by comparing them to one another. This procedure is usually difficult because they are scattered through the literature and generally plotted on incompatible scales. This report presents a group of 35 such measurements which are taken from the literature and transferred to a standardized graphical format that permits direct comparisons between data. The curves are grouped according to the gross experimental conditions at the time of the rocket flight, that is, day or night, summer or winter, active or quiet sun.

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I. INTRODUCTION

For the past two and a half years, the author has been engaged in digital computation of radio raypaths in the ionosphere. In such work, the accuracy required of mathematics and computer programming depends on the accuracy with which the ionosphere can be represented by a model. If an unrealistic electron-density profile is selected for computation, the results are often useless and sometimes misleading. Consequently, a literature search was conducted to gather a large amount of data concerning the electron-density distribution in the ionosphere, with particular emphasis on those measurements acquired by rocket sounding. When these data were all transferred to standardized graphical format, the comparisons proved to be of such wide interest and usefulness that it was decided to present them in this report.

In the literature, altitudes are measured in kilometers, kilofeet, nautical miles, and statute miles. This is unfortunate, but at least the majority of the altitude axes are linear scales. The electron-density axes in the literature are labeled in a large variety of ways, the most common of which incorporate either linear or logarithmic scales. Some data are presented on a rather strange logarithmic scale which begins at zero! In such cases, data points which lie along the questionable scale are not reproduced in this paper. Sometimes the electron density was presented in terms of plasma frequency. The particular choice of the vertical- and the horizontal-axis scales seemed to depend on the identity of the contracting agency and the nature of the rocket instrumentation. This situation makes it very difficult for the casual reader to compare the electron-density profiles derived by two or more different authors, and therein lies the key to the usefulness of this project.

One note of caution: some scatter between data points is a natural consequence of the measurement techniques which are used. Thus, during the flight of a rocket, successive readings may be taken which differ from one another because of some form of instrumental error. This is unfortunate because the detailed manner in which the electron density varies during the rocket flight is one of the most interesting results

that could be obtained. Yet, not many authors give a clear indication as to how much confidence can be placed in the small details along the curve of the data. Some authors avoid the question entirely by simply presenting all of the data points and letting the reader decide for himself just where the electron-density curve must lie.

For this study, some smoothing of curves was arbitrarily carried out when it appeared that the data from the literature contained a good deal of scatter due to instrumental error. The reader who is interested in electron-density variations within a small height increment (e.g., 3 to 5 km) would be well advised to consult the original papers to learn the degree of confidence which may be placed in details.

The literature search which produced these curves was by no means complete, and, in fact, the most recent data included here was taken in 1962. However, the search was carried on until it was found that most curves referenced in new papers had already been located in a previous reference. Thus, it is probably safe to estimate that this report contains half of all the data available in the literature by the end of 1962.

Since each curve is valuable in its own right, it is common for several authors to present the same data. An attempt has been made to credit the original author on each of these curves and if errors exist, apologies are extended to the parties involved.

II. PRESENTATION OF DENSITY MEASUREMENTS

In this section all the data are presented, grouped according to the time of day, the season, and the sun's activity. The sun was judged to be either active or quiet according to the date of occurrence in the sunspot cycle which was determined from Ref. 1. Daytime was arbitrarily defined to be the hours between 0600 and 1800, local time. Similarly, summer was judged to exist during all the months between and including April and September. In order to fill in the D region, only a single reference was used, and this particular data is intended to serve only as a general guide and not as a definitive study.

Since groups of curves have been formed according to three binary criteria, there should be ($2^3 = 8$) groups. However, only six groups are actually given here because there were very few rocket soundings found during "quiet sun, summer nighttime" or during "active sun, winter nighttime." The records that did fall into these two categories have been included in other groups where they might logically fall with the exercise of a little flexibility in the definitions of the criteria.

The six groups, and the corresponding figure that illustrates each group, are listed below. Each figure shows all the curves which were found for the rocket launches, grouped by the sun's activity, the season, and the time of day respectively. In addition, each figure contains the source from which the curves were obtained and other pertinent information.

<u>Group</u>	<u>Figure Number</u>
Quiet sun, winter daytime	1
Quiet sun, summer daytime	2
Quiet sun, winter nighttime	3
Active sun, winter daytime	4
Active sun, summer daytime	5
Active sun, summer nighttime	6

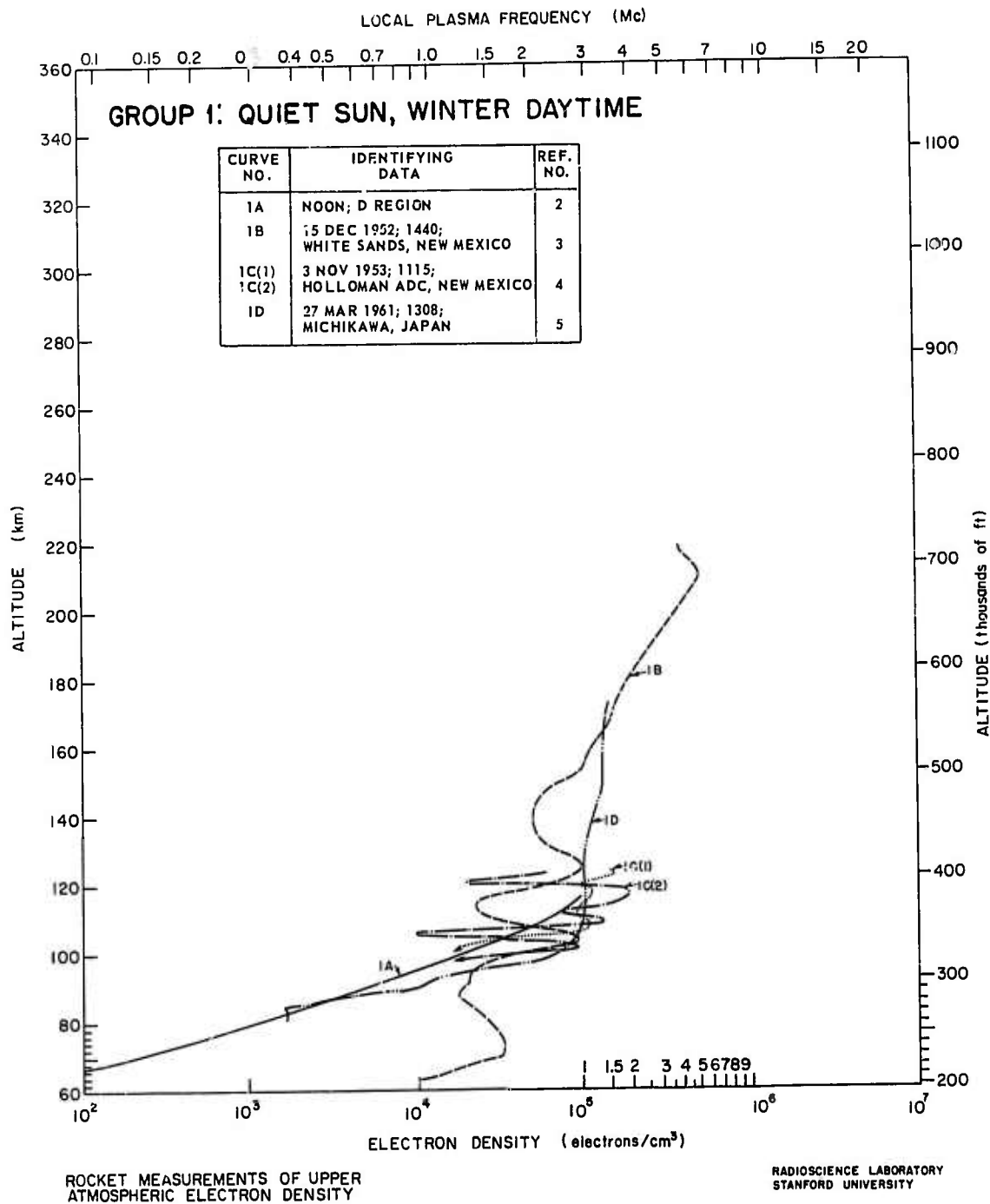


FIG. 1. ROCKET MEASUREMENTS MADE DURING TIMES OF QUIET SUN IN WINTER DAYTIME.

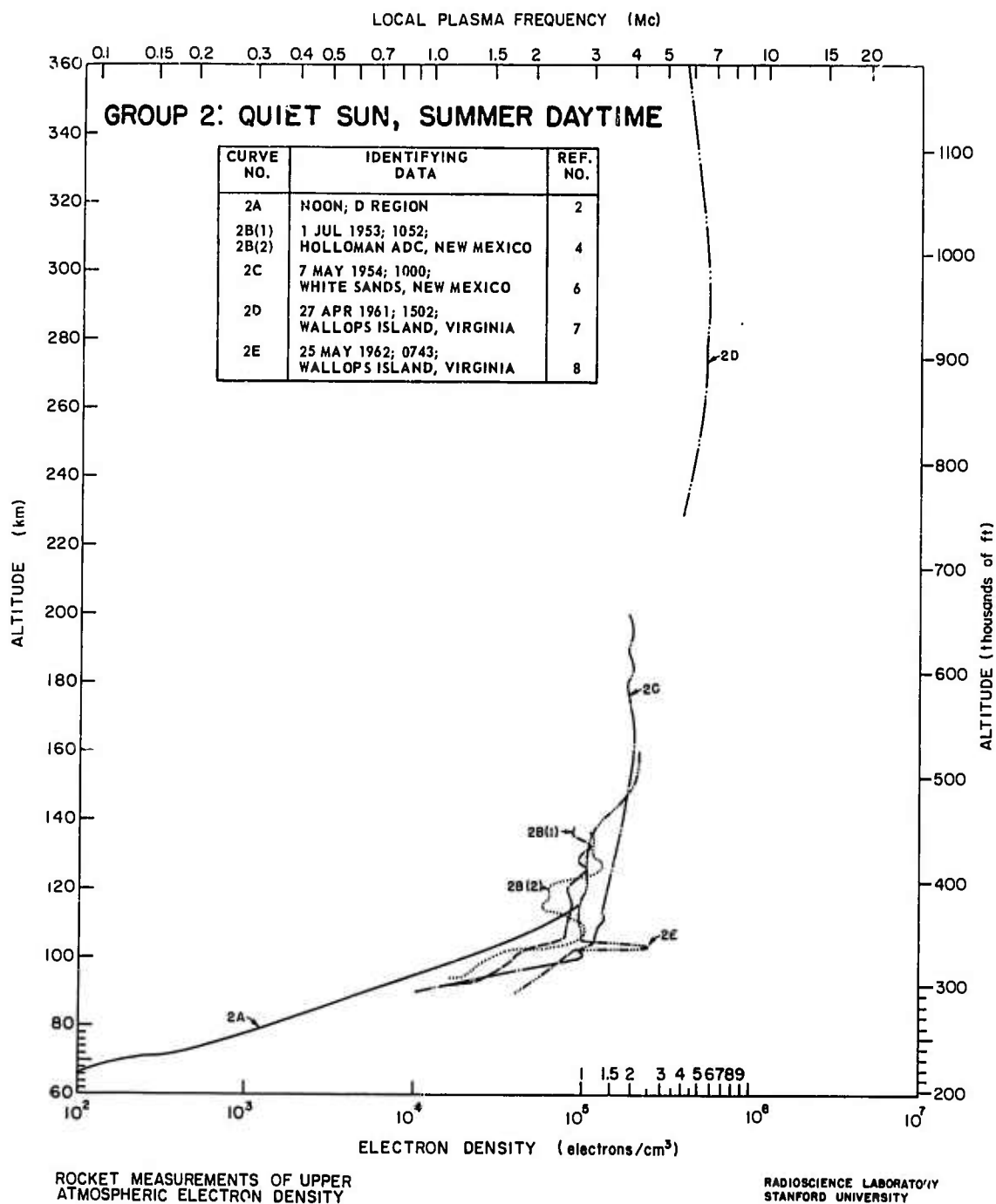


FIG. 2. ROCKET MEASUREMENTS MADE DURING TIMES OF QUIET SUN IN SUMMER DAYTIME.

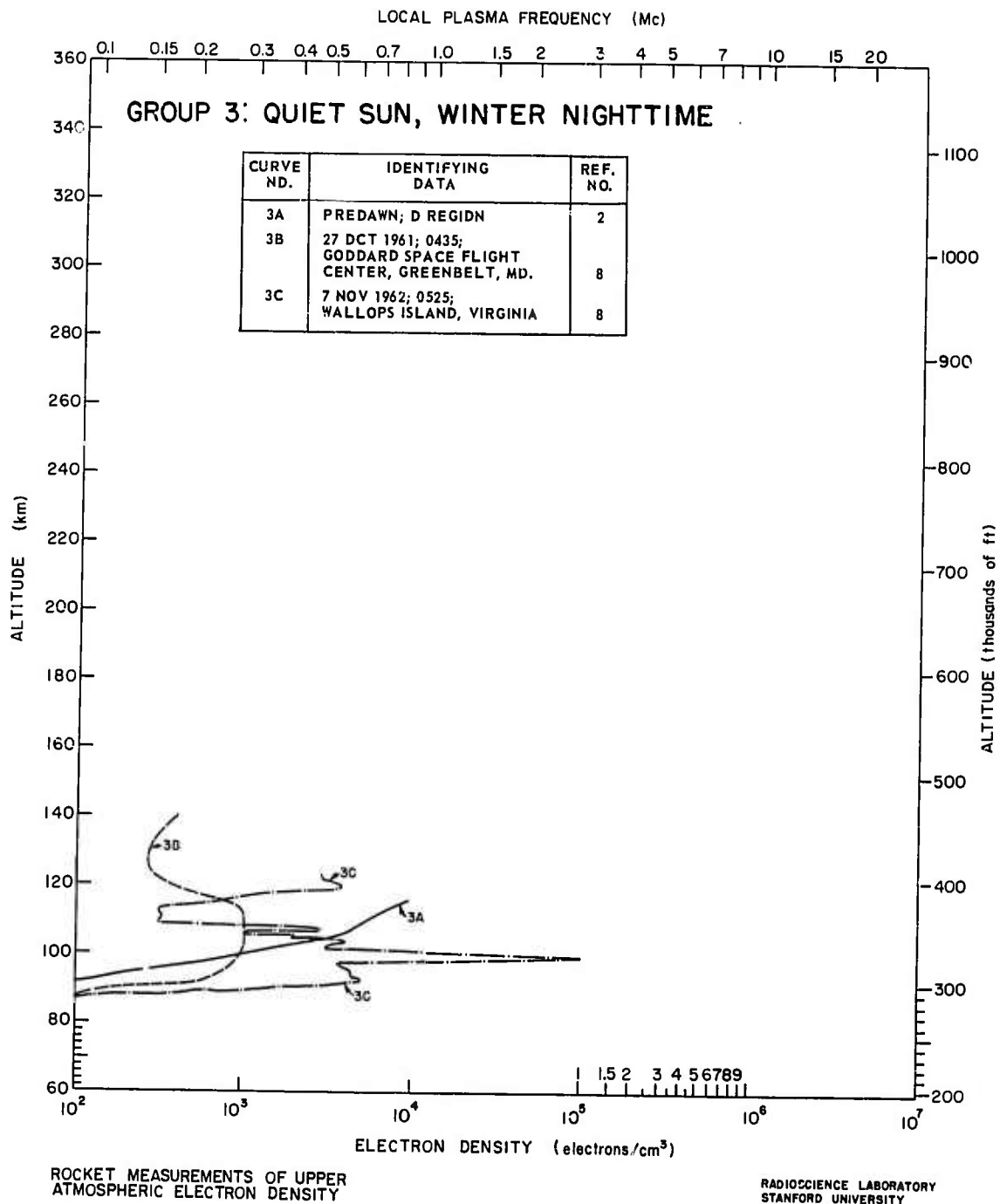
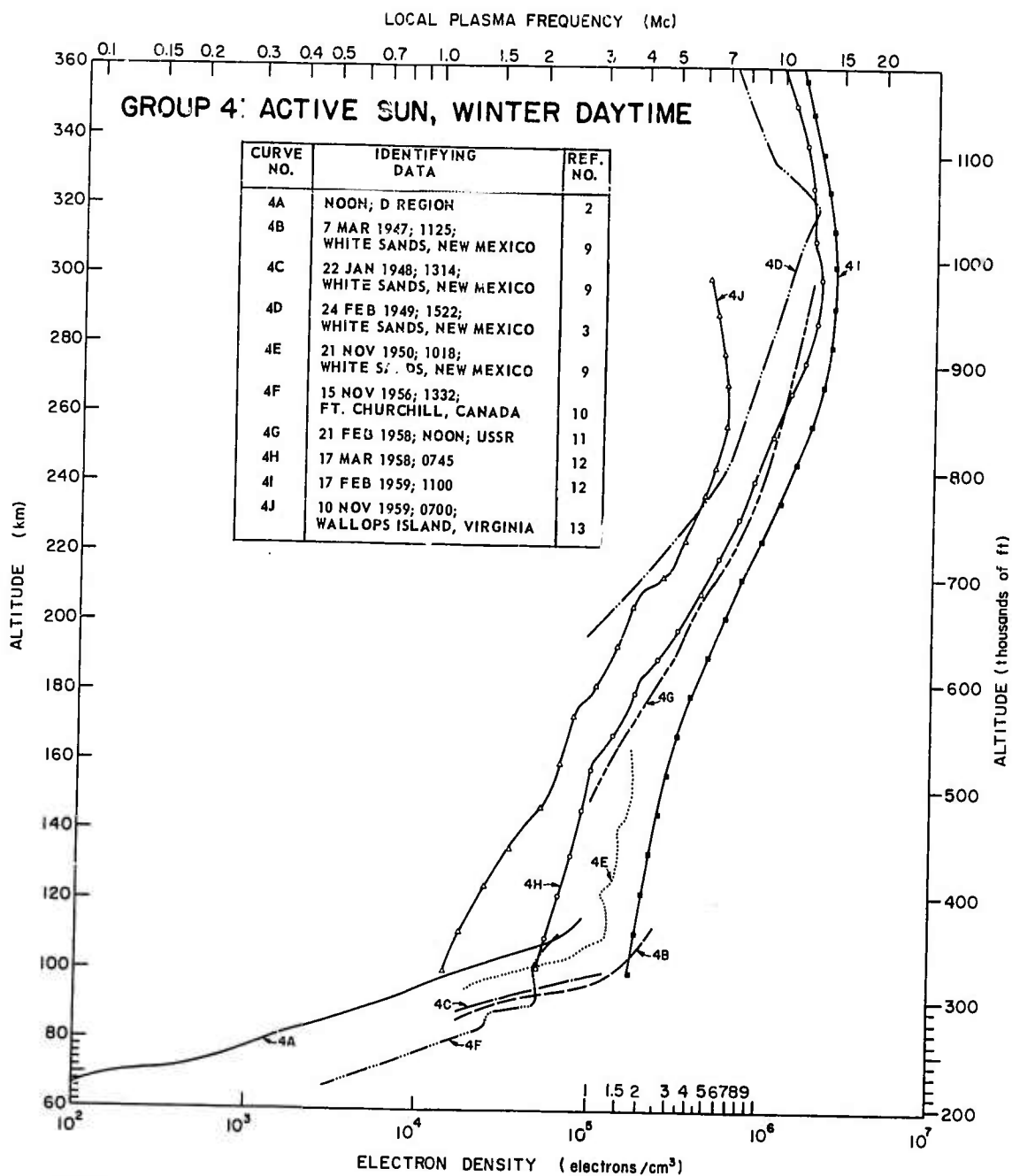


FIG. 3. ROCKET MEASUREMENTS MADE DURING TIMES OF QUIET SUN IN WINTER NIGHTTIME.



ROCKET MEASUREMENTS OF UPPER
ATMOSPHERIC ELECTRON DENSITY

RADIO SCIENCE LABORATORY
STANFORD UNIVERSITY

FIG. 4. ROCKET MEASUREMENTS MADE DURING TIMES OF ACTIVE SUN IN WINTER DAYTIME.

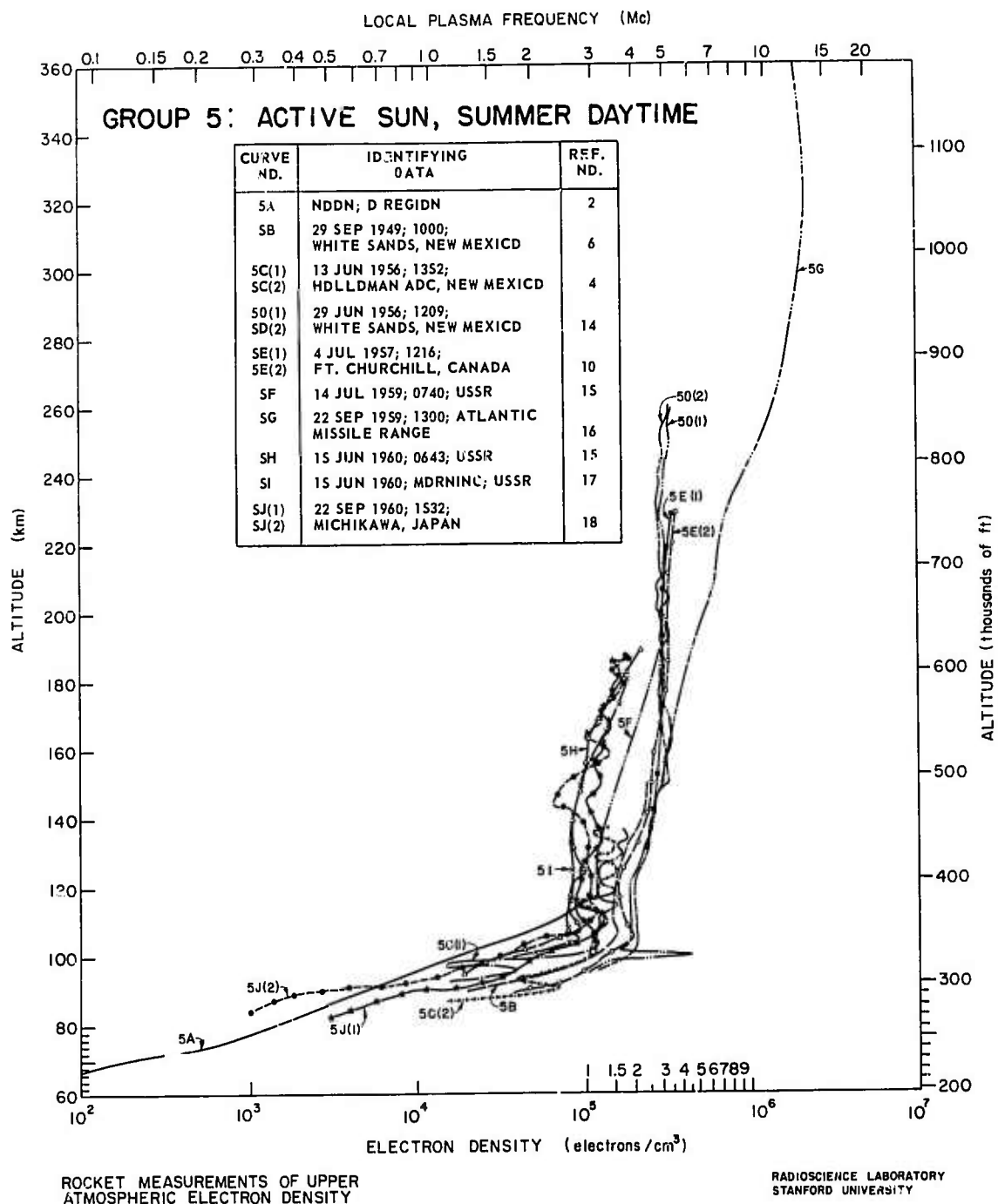


FIG. 5. ROCKET MEASUREMENTS MADE DURING TIMES OF ACTIVE SUN IN SUMMER DAYTIME.

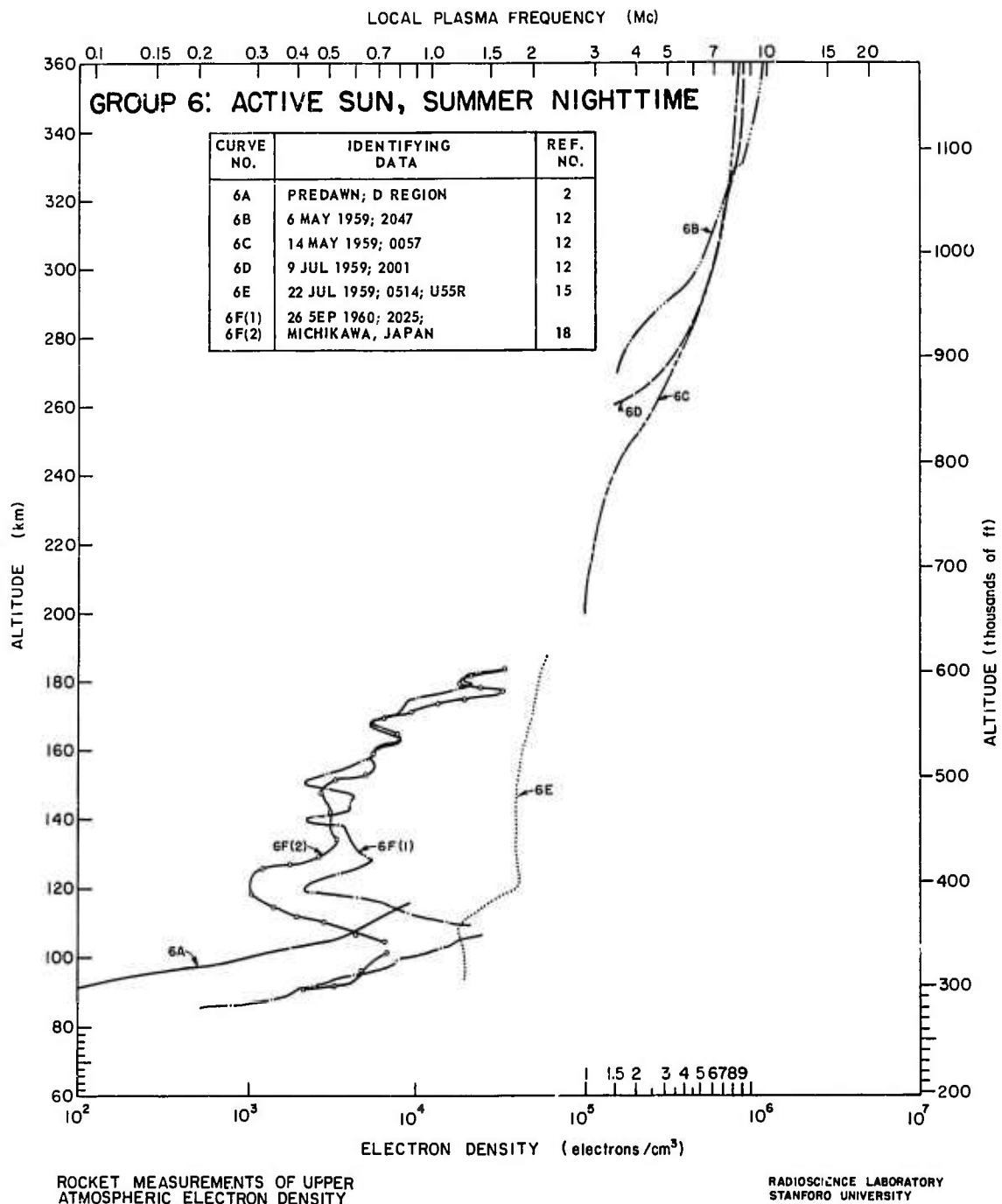


FIG. 6. ROCKET MEASUREMENTS MADE DURING TIMES OF ACTIVE SUN IN SUMMER NIGHTTIME.

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